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Single Bump on a Shell Fabrication

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To: Distribution

From: Bob Cook

Subject: Single bump on a shell fabrication

At this morning's fill-tube surrogate working group meeting we tentatively decided on a single bump on a shell for the single March shot. This memo shows the calculations needed as background to fabricate such a bump by depositing an appropriate sized drop of polystyrene solution (i.e. the glue) to a shell as discussed in this morning's meeting. While writing this I had another idea for fabricating a bump, which I quickly outlined at the end of this memo. I am distributing this calculation primarily so that group members can quickly check the calculations and ideas and if without error to provide a framework for initial fabrication efforts.

Steve Haan modeled the bump as a Gaussian for convenience, the shape is thought not to be important (at least for high mode number defects) but the mass is. So first we need to know the volume of a Gaussian bump, and then with the material density have the mass.

Lets assume a flat surface and a Gaussian bump given by

$$z = Ae^{-(x^2+y^2)/2a^2} = Ae^{-r^2/2a^2} \quad (1)$$

where A is the bump amplitude and a determines the "steepness" of the Gaussian. The second expression in terms of r simply transforms the expression from Cartesian to polar coordinates, (r, θ) .

In the meeting Steve gave the approximate bump size by a full width at half max, for a Gaussian this occurs when

$$A/2 = Ae^{-r_{\text{hwfm}}^2/2a^2} \quad (2)$$

or

$$w_{\text{hm}} = 2r_{\text{hwfm}} = 2a\sqrt{2\ln 2} \approx 2.355a \quad (3)$$

The volume, V_b , of the Gaussian bump is given by

$$V_b = \int_0^A \pi r^2 dz = \pi \int_0^A 2a^2 \ln(A/z) dz = 2\pi a^2 A \quad (4)$$

where r^2 is taken from eq 1. Thus the mass in the bump, m_b , is

$$m_b = 2\pi a^2 A \rho_b \quad (5)$$

where ρ_b is the density of the bump material.

Lets look at the "straw man" bump we decided on in the meeting. It had a height of 1.5 μm and a full width at half max of 60 μm . Using eq 3 above the value of a is 25.48 μm , and of course A is 1.5 μm . The volume is thus 6118.7 μm^3 , which is $6.12 \times 10^{-9} \text{ cm}^3$. I'm guessing that Steve used 1.05 as the density of CH in the code, the density of polystyrene (empirical formula CH) is also about 1.05 g/cm^3 , and thus the mass of the desired bump would be $6.43 \times 10^{-9} \text{ g}$.

So lets now switch to application of the bump to a shell surface. The idea is to apply a drop of polystyrene solution to the surface with the right mass of polystyrene, and then have the solvent evaporate to leave a bump. Clearly the solution has to be pretty viscous so the drop doesn't extend more than the desired width. Let's start by figuring out how large is a drop of solution that contains $6.43 \times 10^{-9} \text{ g}$ of polystyrene. I'll assume toluene as a solvent, density 0.867 g/cm^3 , and additive volumes. Thus the volume of a drop, V_d , containing $6.43 \times 10^{-9} \text{ g}$ of polystyrene as a function of the composition ($\text{wt}\% = \text{wt PS}/\text{tot wt}$) is

$$V_d = \frac{6.43 \times 10^{-9}}{1.05} + \frac{6.43 \times 10^{-9} \left(\frac{100 - \text{wt}\%}{\text{wt}\%} \right)}{0.867} \text{ cm}^3 . \quad (6)$$

This is plotted on the top of the next page. The tough part is knowing what concentration is viscous enough, and how to deposit a drop of the right size. I don't know the answers to those questions, probably some experimentation with small drops on a simple flat plasma polymer covered surface will provide the answers.

Another idea.

While writing this and thinking about how difficult it might be, I thought of another idea that might be both easier and offer more control. The idea is quite simple. If we simply mask the desired shell with a film that has a pinhole in it of the right size positioned facing the coater and coat with plasma polymer for the right amount of time we will "make" a bump. A cartoon of the method is shown at the bottom of the next page. The key variables are the size of the pinhole, the distance of the mask from the pole of the shell, and the thickness of the mask. The last is important because the material coming out of the coater tube is not ballistically straight down. Steve Letts and company will do some demonstration studies on a flat first. A problem for shells will be controlling the positioning of the mask, but maybe there is a simple solution to this as well. Characterizing the bump will be done by Wyko Interferometry and should be straightforward.

